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Dopravní plánování a modelování (11 DOPM)

Lekce 2: Nástroje dopravního plánování

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Obsah přednášky

- Cíle dopravního plánování
- Přehled nástrojů dopravního plánování
- Srovnání jednotlivých nástrojů

Diskuse

- Co jsou podle vás nástroje pro analýzu dopravy (traffic analysis tool)?

Nástroje dopranví analýzy (Traffic analysis tools)

- Popisují množinu softwarových analytických produktů, procesů a metodologií, které podporují různé oblasti dopravní analýzy.
- Zahrnují přístupy jako
  - sketch-planning,
  - Plánování a modelování poptávky (travel demand modeling),
  - Optimalizaci signálních plánů (traffic signal optimization),
  - Dopravní simulaci (traffic simulation).

Přehled těchto nástrojů je dostupný zde:

- http://ops.fhwa.dot.gov/trafficanalysistools/tat_vol2/sectapp_e.htm

Diskuze

- K čemu potřebujeme nástroje dopravní analýzy?

Role nástrojů dopravní analýzy

1. Zlepšit rozhodovací proces
2. Ohodnotit / vybrat a množiny alternativních řešení
3. Zlepšit návrh systému a snížit cenu (čas) za vyhodnocení
4. Snížit vliv na dopravu
5. Prezentovat strategie řešení veřejnosti / stakeholderům
6. Provozovat a řídit existující kapacitu komunikací
7. Monitorovat výkonnost systémů

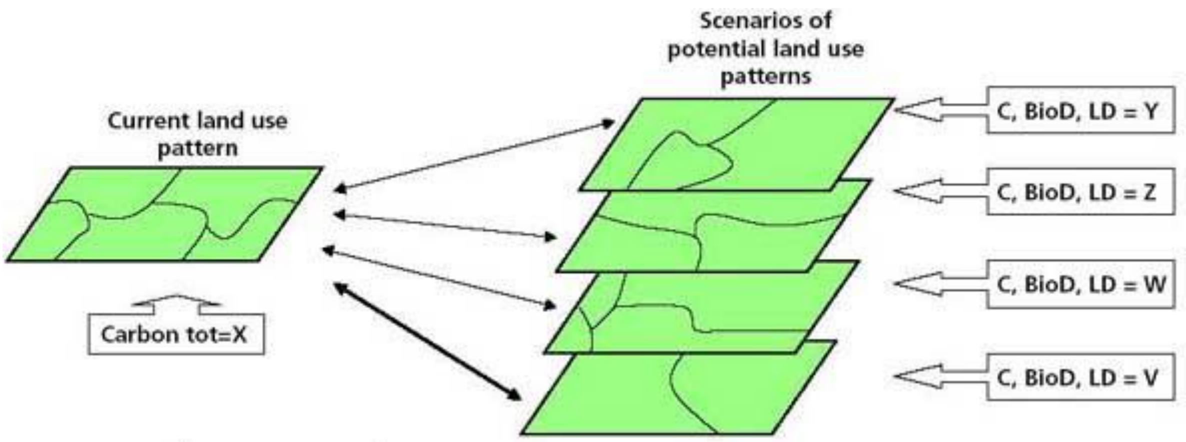
1. Zlepšit rozhodovací proces

- Traffic analysis tools help practitioners arrive at better planning/engineering decisions for complex transportation problems.
- Used to estimate the impact of the deployment of traffic management and other strategies,
- Used to help set priorities among competing projects.
- In addition, they can provide a consistent approach for comparing potential improvements or alternatives.

Rozhodovací kostka

2. Evaluate and prioritize planning/operational alternatives

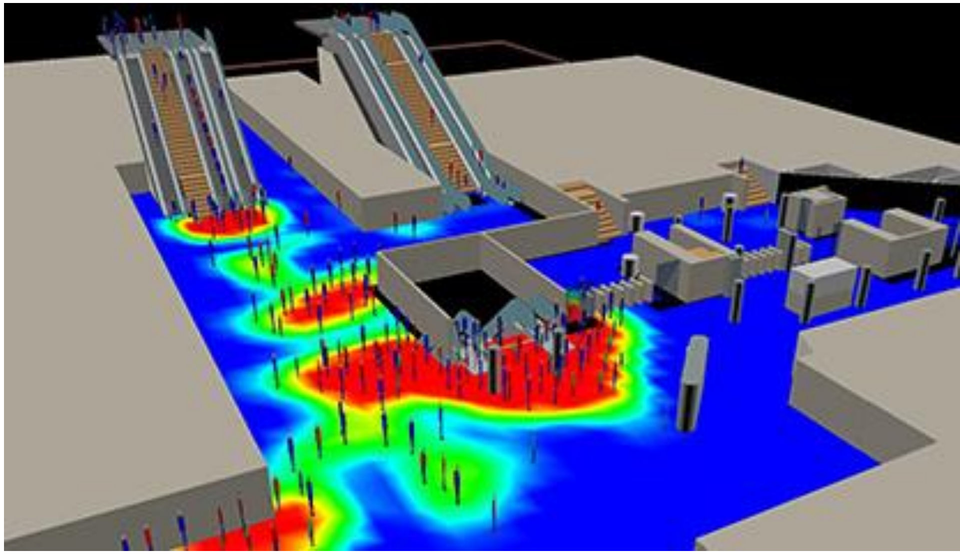
- This typically involves comparing “no build” conditions with alternatives, which include various types of potential improvements.
- The impacts are reported as performance measures and are defined as the difference between the no-build and alternative scenarios.
- The results can be used to select the best alternative or prioritize improvements, increasing the odds of having a successful deployment.



3. Improve design and evaluation time and costs

- Traffic analysis tools are relatively less costly when compared to pilot studies, field experiments, or full implementation costs.
- Furthermore, analytical tools can be used to assess multiple deployment combinations or other complex scenarios in a relatively short time.

STEPS - a microsimulation tool to predict pedestrian movement under both normal and emergency conditions



4. Reduce disruptions to traffic

- Traffic management and control strategies come in many forms and options, and analytical tools provide a way to cheaply estimate the effects prior to full deployment of the management strategy.
- They may be used to initially test new transportation management systems concepts without the inconvenience of a field experiment.

5. Present/market strategies to the public/stakeholders

- Some traffic analysis tools have excellent graphical and animation displays, which could be used as tools to show “what if” scenarios to the public and/or stakeholders.

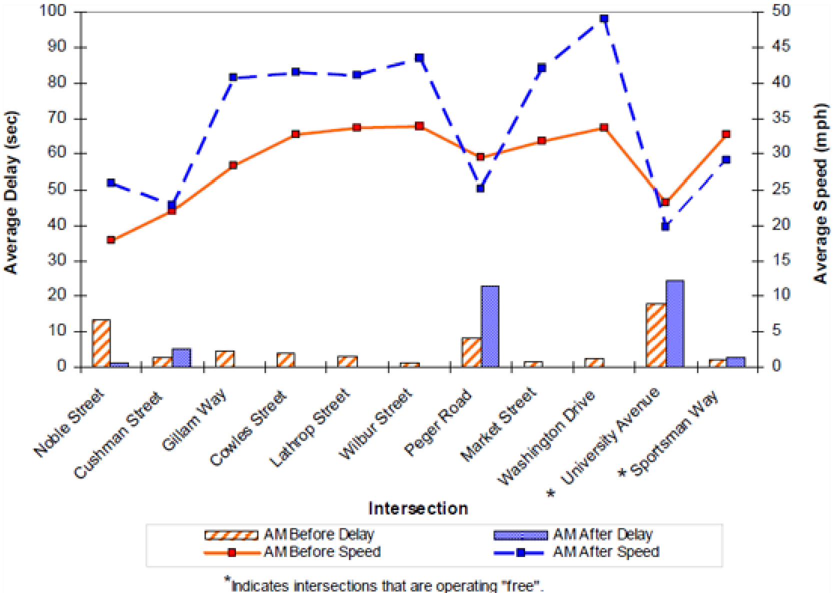
6. Operate and manage existing roadway capacity

- Some tools provide optimization capabilities, recommending the best design or control strategies to maximize the performance of a transportation facility.

7. Monitor performance

- Analytical tools can also be used to evaluate and monitor the performance of existing transportation facilities.
- In the future, it is hoped that monitoring systems can be directly linked to analytical tools for a more direct and real-time analysis process.

- Installation of a virtual detector does not cost anything and can be used to measure more advanced features (travel time, etc.)



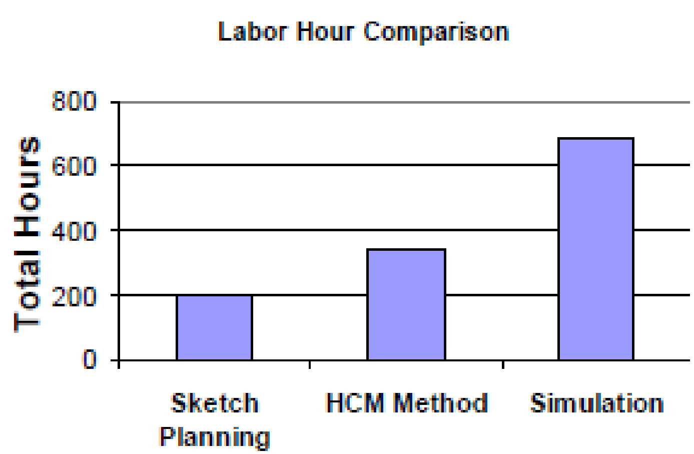
Categories of Traffic Analysis Tools

- Sketch-planning tools
- Travel demand models (Urban Transportation Planning System -UTPS)
- Analytical/deterministic tools (HCM-based)
- Traffic signal optimization tools
- Macroscopic simulation models
- Mesoscopic simulation models
- Microscopic simulation models

Sketch-planning tools

- Produce general order of-magnitude estimates of travel demand and traffic operations in response to transportation improvements.
- Such techniques are primarily used to prepare preliminary budgets and proposals, and are not considered to be a substitute for the detailed engineering analysis often needed later in the project implementation process.
- Typically the simplest and least costly of the traffic analysis techniques.
- Perform some or all of the functions of other analytical tool types, using simplified analyses techniques and highly aggregated data
- Usually limited in scope, analytical robustness, and presentation capabilities.
- Often, they are spreadsheet-based or GIS-based techniques

In Juneau, Alaska, sketch planning traffic analysis tools helped achieve community consensus by quickly and clearly highlighting the lane and interchange requirements associated with different alternatives.

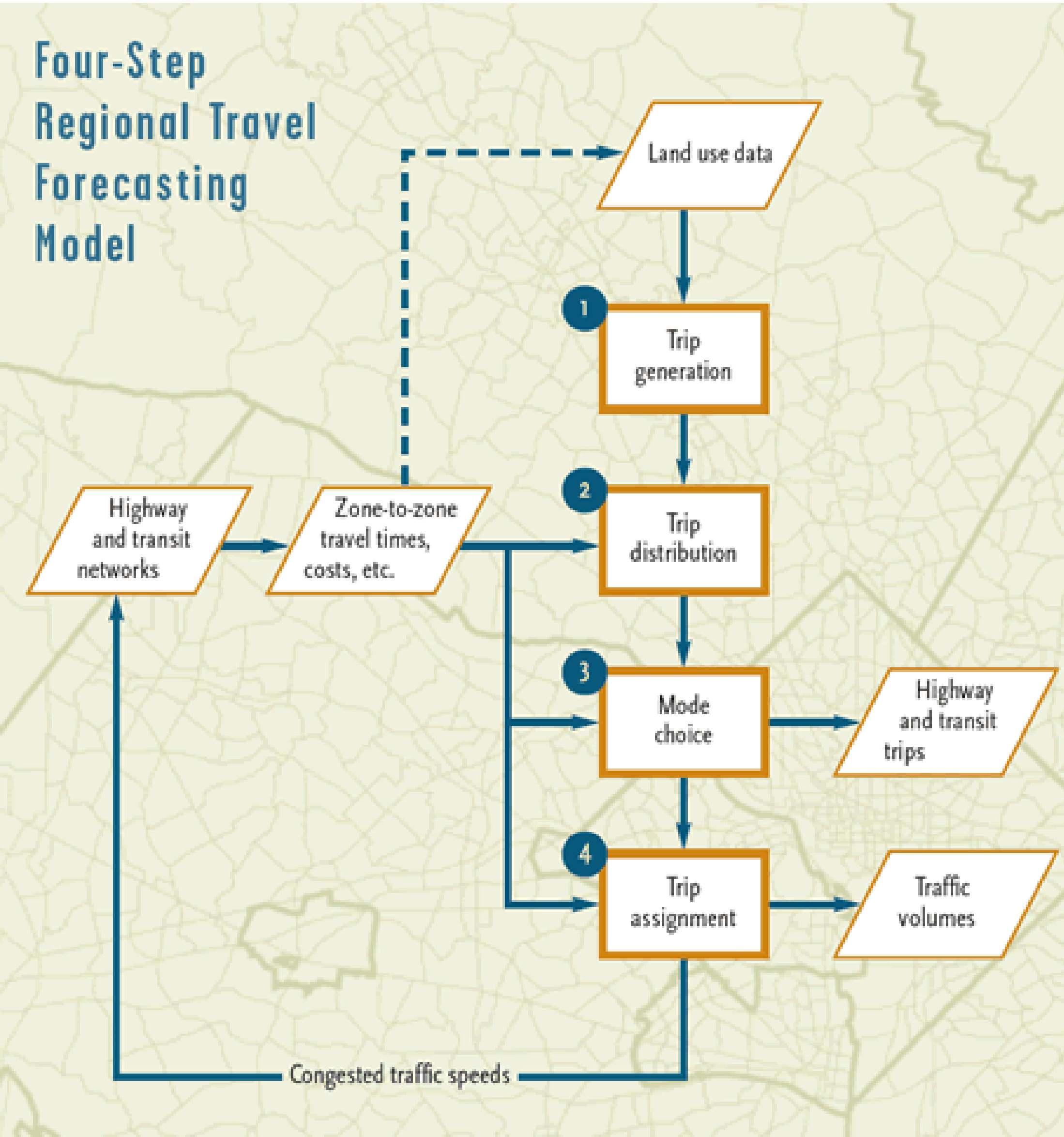


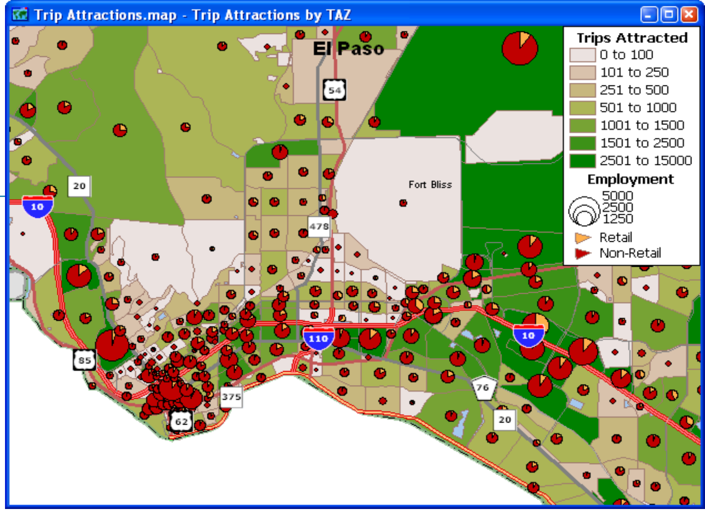
Travel demand models (UTPS)

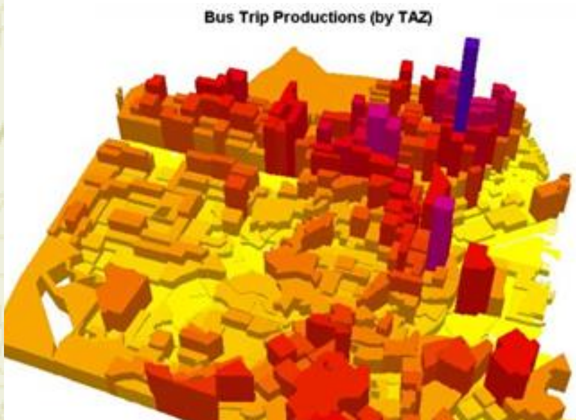
- Urban Transportation Planning System (UTPS)
- Four Step Model (FSM, 4SM)

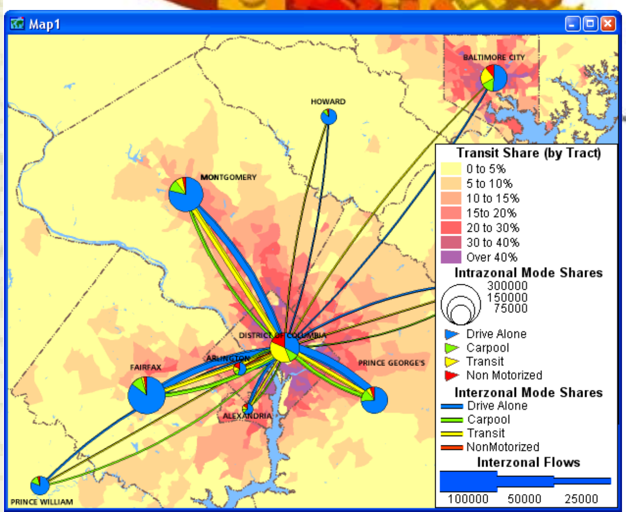
- Travel demand models were originally developed to determine the benefits and impact of major highway improvements in metropolitan areas.
- However, they were not designed to evaluate travel management strategies, such as intelligent transportation systems (ITS)/operational strategies.
- They have only limited capabilities to accurately estimate changes in operational characteristics (such as speed, delay, and queuing) resulting from implementation of ITS/operational strategies.
- Four step model:
  - See Next slide

Four Step Model (UTPS)







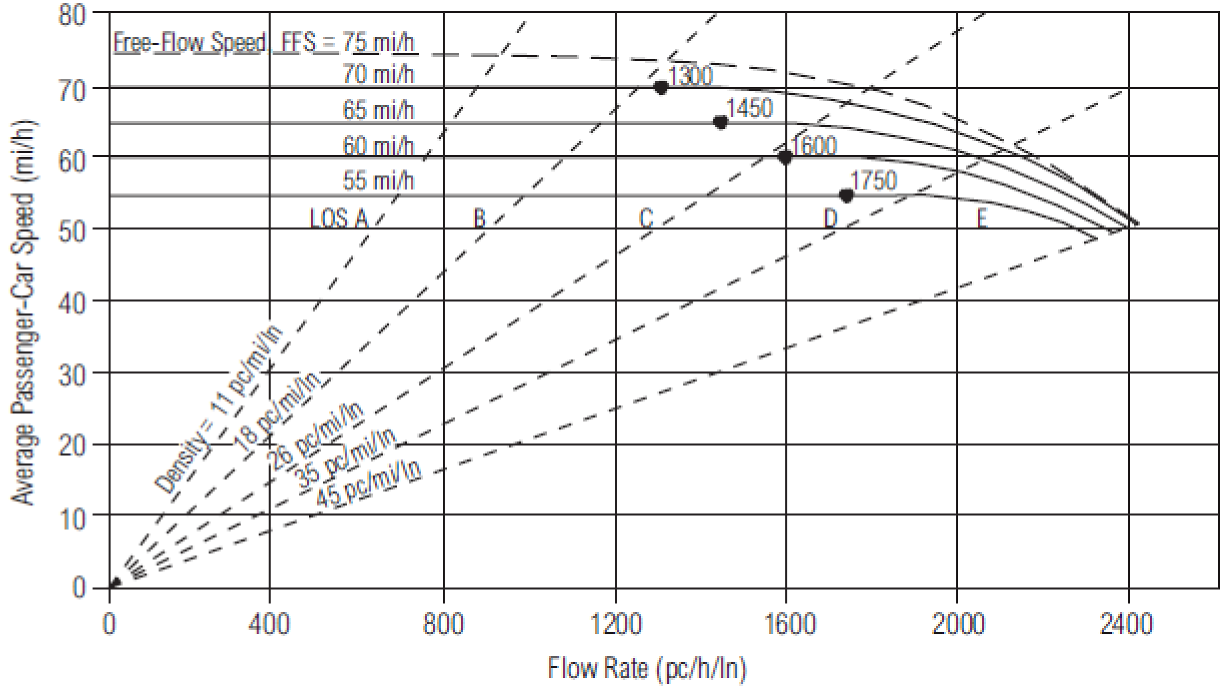


Analytical/deterministic tools (HCM-based)

- Most analytical/deterministic tools implement the procedures of the Highway Capacity Manual (HCM).
- These tools quickly predict capacity, density, speed, delay, and queuing on a variety of transportation facilities and are validated with field data, laboratory test beds, or small-scale experiments.
- Analytical/deterministic tools are good for analyzing the performance of isolated or small-scale transportation facilities
- However, they are limited in their ability to analyze network or system effects.
- Keeping them up to date is relatively costly

LOS	Average delay in seconds per vehicle	Description of motorist perception
A	< 10	Free-flow traffic: "Good" LOS
B	10.1 – 20	Reasonable free-flow
C	20.1 – 35	Stable but unreasonable delay begins to occur
D	35.1 – 55	Borderline "bad" LOS
E	55.1 – 80	"Bad" LOS: long queues
F	> 80	Unacceptable: very high delay, congestion

EXHIBIT 23-3. SPEED-FLOW CURVES AND LOS FOR BASIC FREEWAY SEGMENTS



Note:
Capacity varies by free-flow speed. Capacity is 2400, 2350, 2300, and 2250 pc/h/ln at free-flow speeds of 70 and greater, 65, 60, and 55 mi/h, respectively.

For $70 < FFS \le 75$

$(3400 - 30FFS) < v_p \le 2400$

$$S = FFS - \left[\left(FFS - \frac{160}{3}\right)\left(\frac{v_p + 30FFS - 3400}{30FFS - 1000}\right)^{2.6}\right]$$

For $55 \le FFS \le 70$ and for flow rate (v_p)

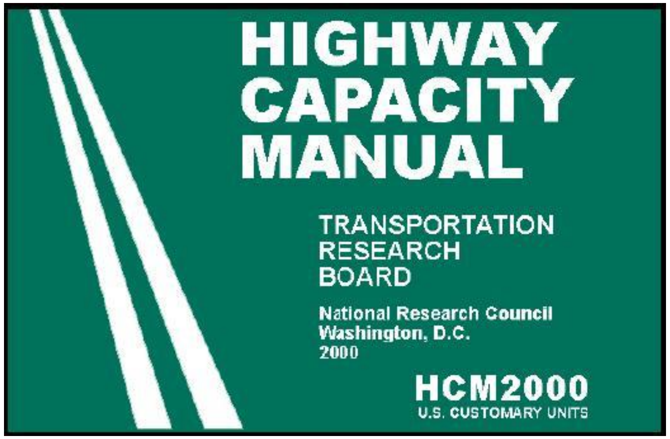
$(3400 - 30FFS) < v_p \le (1700 + 10FFS)$,

$$S = FFS - \left[\frac{1}{9}(7FFS - 340)\left(\frac{v_p + 30FFS - 3400}{40FFS - 1700}\right)^{2.6}\right]$$

For $55 \le FFS \le 75$ and

$v_p \le (3400 - 30FFS)$,

$S = FFS$



Microscopic simulation models

- They simulate the movement of individual vehicles based on car-following and lane-changing theories.
- Typically, vehicles enter a transportation network using a statistical distribution of arrivals (a stochastic process) and are tracked through the network over small time intervals (e.g., 1 second or a fraction of a second).
- Typically, upon entry, each vehicle is assigned a destination, a vehicle type, and a driver type.
- Computer time and storage requirements for microscopic models are large, usually limiting the network size and the number of simulation runs that can be completed.

Mesoscopic simulation models

- Mesoscopic simulation models combine the properties of both microscopic (discussed below) and macroscopic simulation models.
- Mesoscopic models normally describe the traffic entities at a high level of detail, but their behaviour and interactions are described at a lower level of detail
  - As in microscopic models, the mesoscopic models' unit of traffic flow is the individual vehicle.
  - Their movement, however, follows the approach of the macroscopic models and is governed by the average speed on the travel link.
  - Mesoscopic model travel simulation takes place on an aggregate level and does not consider dynamic speed/volume relationships.
- As such, they provide less fidelity than the microsimulation tools, but are superior to the typical planning analysis techniques.

Macroscopic simulation models

- Based on the deterministic relationships of the flow, speed, and density of the traffic stream.
- The simulation in a macroscopic model takes place on a section-by-section basis rather than by tracking individual vehicles.
- They have considerably fewer demanding computer requirements than microscopic models.
- They do not, however, have the ability to analyze transportation improvements in as much detail as the microscopic models.

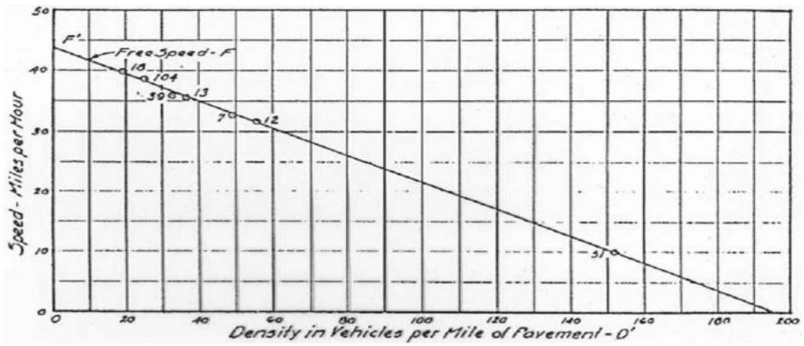
Odvození fundamentálního diagramu

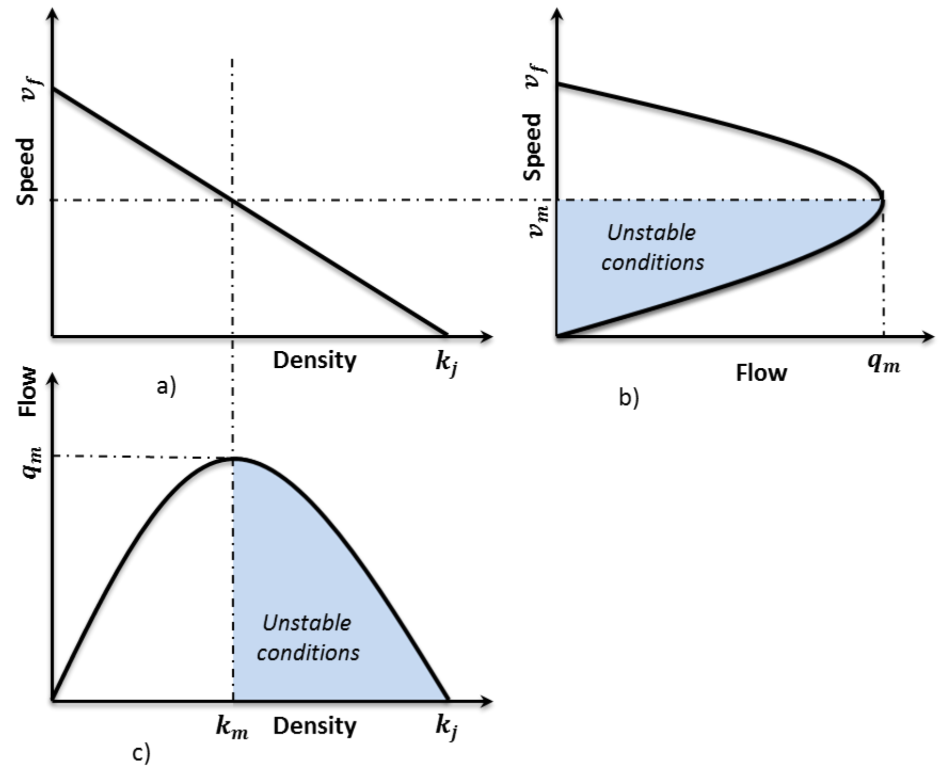
- Jaké znáte základní parametry dopravního proudu?
  - intenzita, *q (voz/h/jízdní pruh)*,
  - hustota *k (voz/km)*, a
  - rychlost *v (km/h)* [15].

Vztah mezi nimi je možné vyjádřit rovnicí

$$q = v.k$$

Greenshieldův lineární model





$$v = v_f . \left(1 - {}^{k}/_{k_j}\right)$$

$$q = v . k$$

$$q = v_f . \left(k - {}^{k^2}/_{k_j}\right)$$

$$q = k_j \left(v - {}^{v^2}/_{v_f}\right)$$

v_f is so called free flow speed, in other words the desired speed,
v_m is called optimal speed when the flow reaches the capacity of the road,
q_m is the maximal flow also denoted as capacity of the given road,
k_m is the critical density when the maximal flow is reached,
k_j is a jam density for which the speed equals to zero.

Proč je fundamentální diagram důležitý?

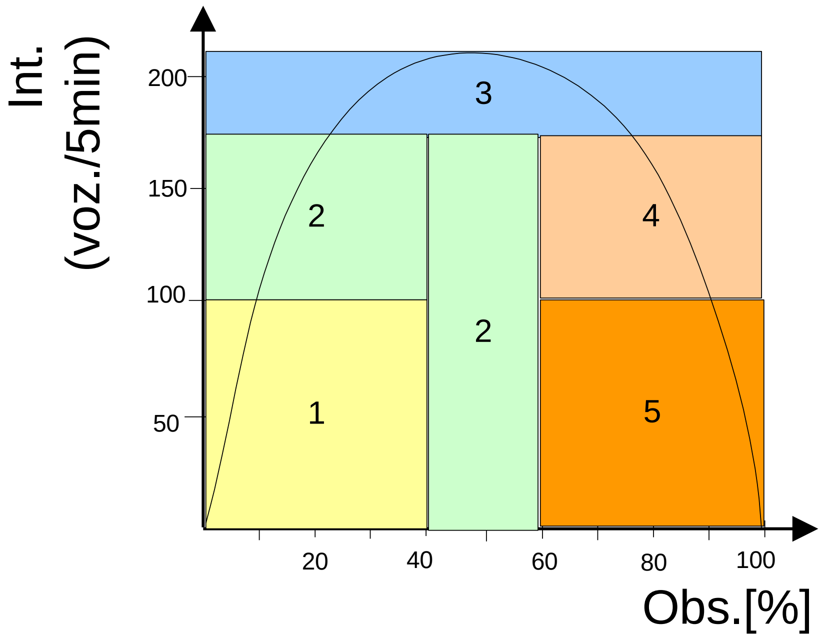
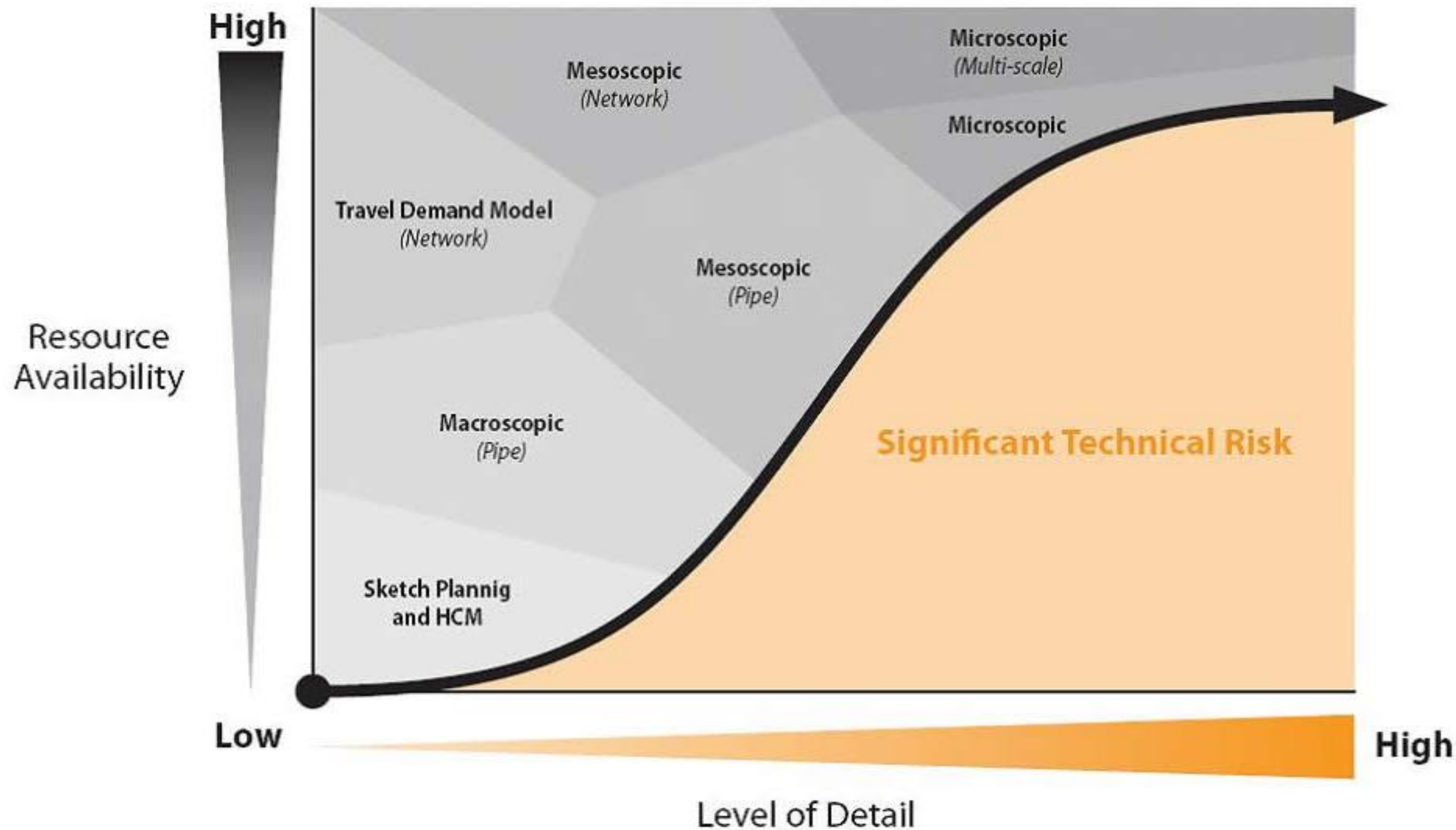


Table 6. HCM2010 LOS definition for 70 mph and 75 mph speed – flow curves (total for three-lane carriageway)

LOS	A		B		C		D		E	
FFS(mph)	70	75	70	75	70	75	70	75	70	75
k_{LOS} (pc/km) ≤	20.5	20.4	33.3	33.3	48.3	48.2	65.1	65.2	83.9	83.9
v_{LOS} (km/h) ≥	112.7	120.7	112.6	118.9	107.4	110.1	97.2	98.0	85.8	85.8
q_{LOS} (pc/h) ≤	2310	2460	3750	3960	5190	5310	6330	6390	7200	7200

Overview of the TDM Tools

Comparison of different tools



Source: http://ops.fhwa.dot.gov/wz/traffic_analysis/tatv9_wz/sec4.htm

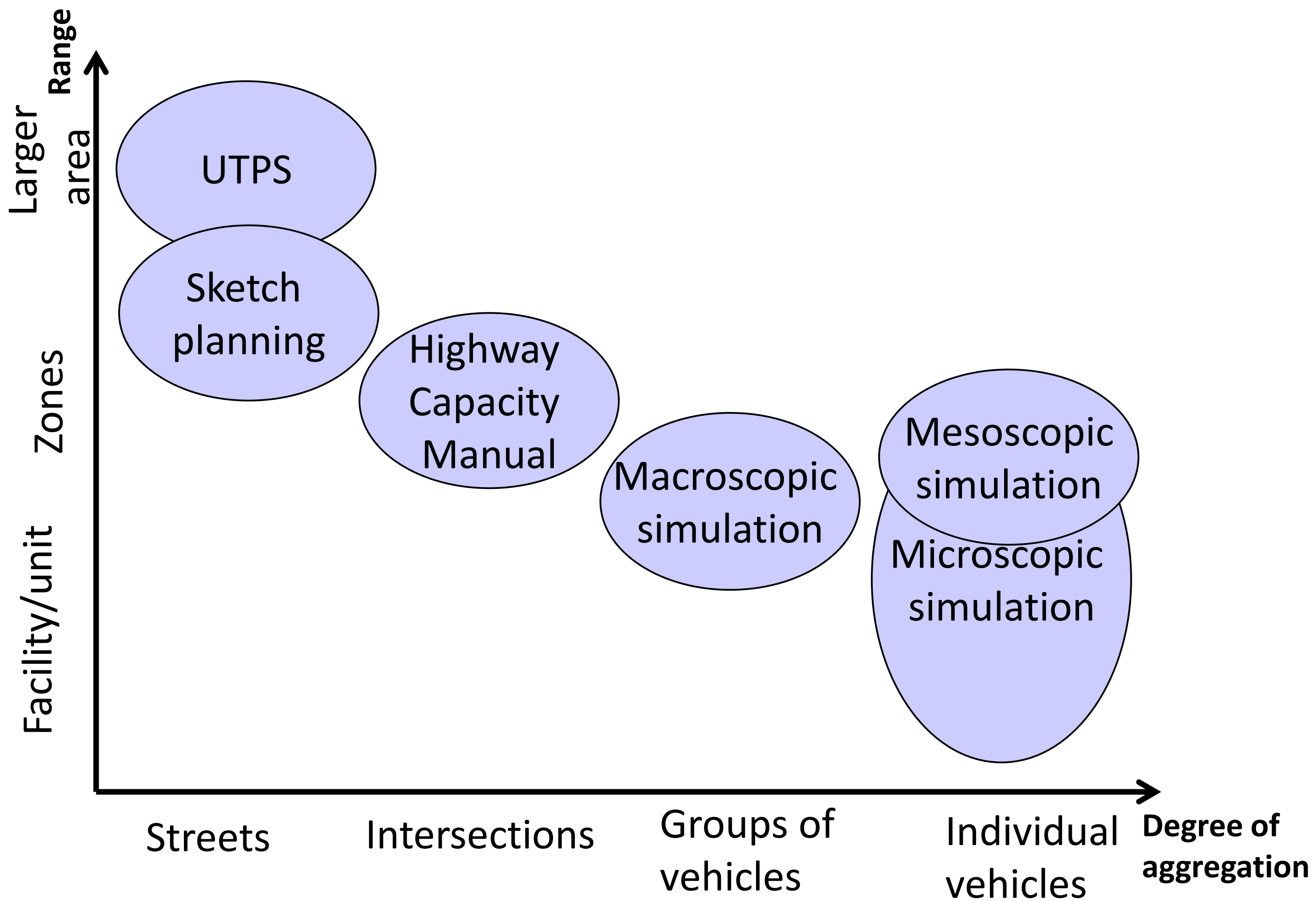
Discussion

- How would you assign the following tools
  1. Sketch planning
  2. UTPS
  3. Microscopic simulation
  4. Macroscopic simulation
  5. Highway capacity manual

into a graph according to

- Geographic area coverage (facilities / zones / large areas)
- Point of view/ Degree of aggregation (vehicles / groups of vehicles / intersections / streets)

Geographical area coverage

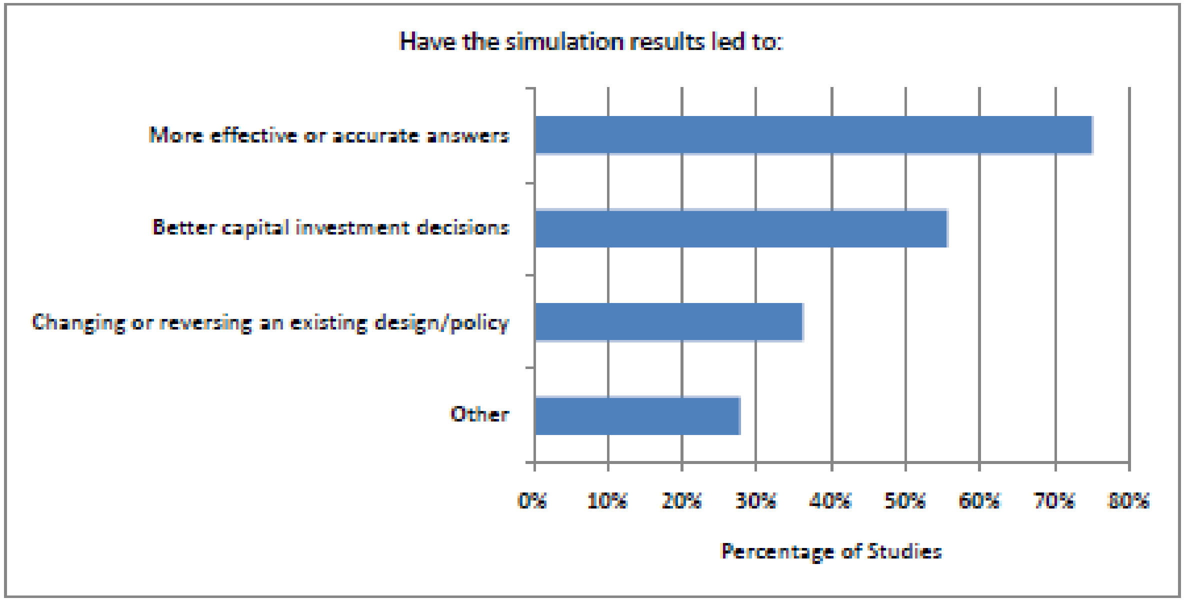


Simulation Strengths and Limitations

- Effective in evaluating the dynamic evolution of traffic congestion
- Can evaluate the interference that occurs when congestion builds up at one location and impacts the capacity of another location
- Can model the variability in driver/vehicle characteristics
- Can be used in hybrid solution to address new ITS related features

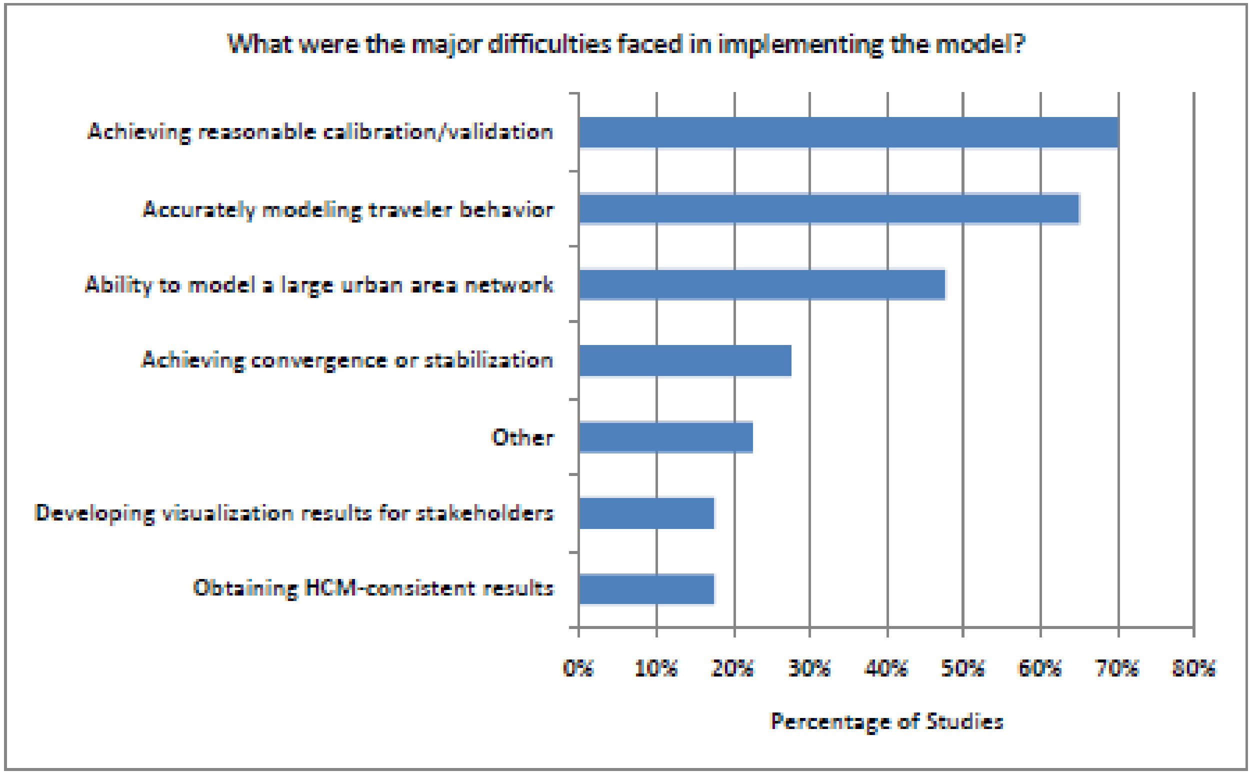
- There may be easier ways to solve the problem; consider all possible alternative ways (analytical models)
- Some users may apply microsimulation packages and treat them as black boxes and really do not understand what they represent
- Some users may apply simulation models and not know or appreciate model limitations and assumptions.
- Can be time-consuming and expensive; do not underestimate time and cost
- Requires considerable input characteristics and data, which may be difficult or impossible to obtain
- Calibration, validation and verification or auditing is required, if overlooked, it could make the model useless
- The algorithms are mostly developed independently and are not subject to peer review and acceptance in the professional community

Benefits of using microsimulation models (survey results)



Source: http://www.statewideplanning.org/_resources/259_NCHRP-08-36-90.pdf

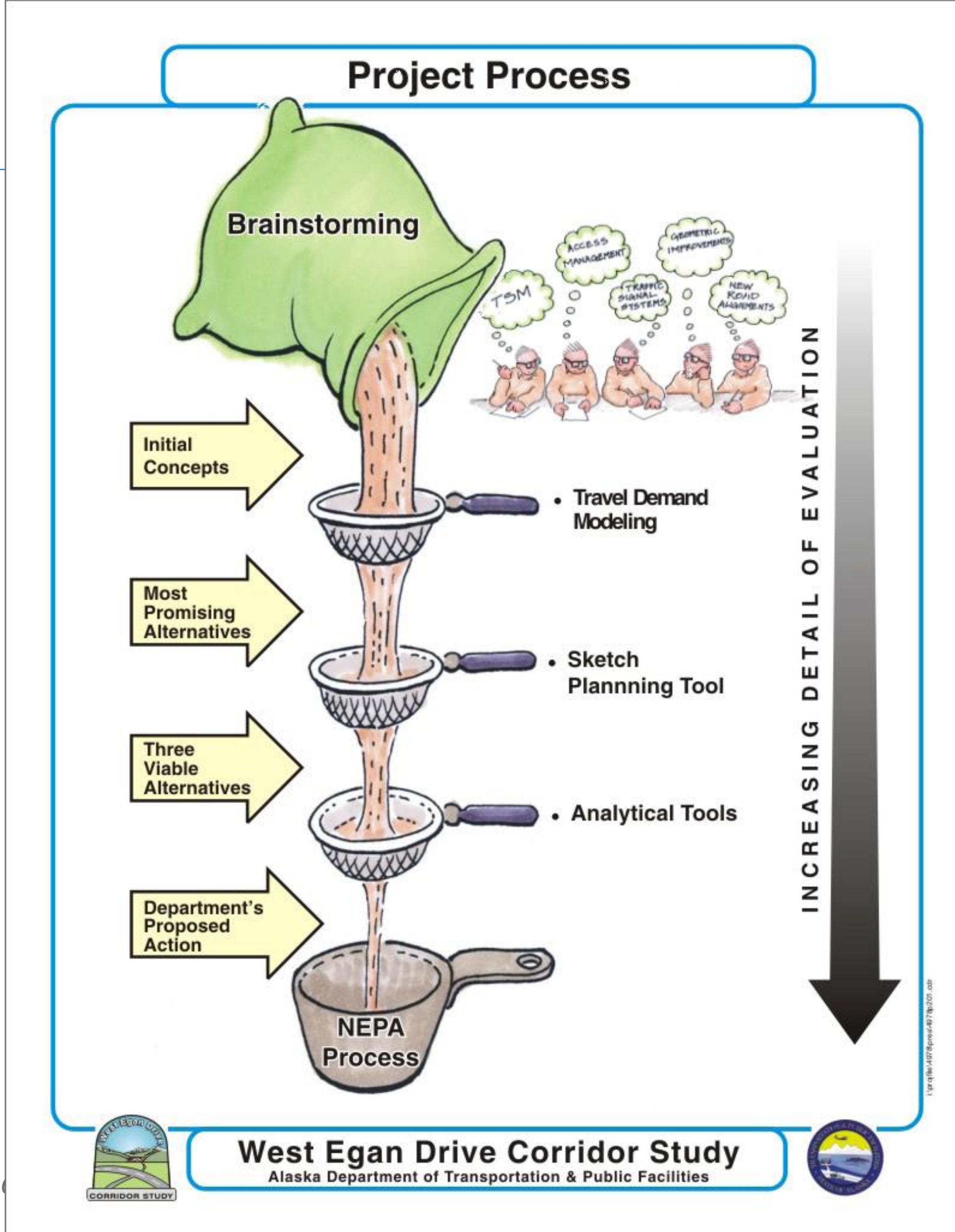
Major difficulties Implementing Microsimulation models (survey results)



Source: http://www.statewideplanning.org/_resources/259_NCHRP-08-36-90.pdf

Criteria for Selecting the Appropriate Type of Traffic Analysis Tool

- Geographic scope
  - Ability to analyze the appropriate geographic scope or study area for the analysis, including an isolated intersection, single roadway, corridor, or network.
- Facility types
  - Capability of modeling various facility types, such as freeways, high-occupancy vehicle (HOV) lanes, ramps, arterials, toll plazas, etc.
- Travel modes
  - Ability to analyze various travel modes, such as single-occupancy vehicle (SOV), HOV, bus, train, truck, bicycle, and pedestrian traffic.
- Strategies and behavior
  - Ability to analyze various traffic management strategies and applications, such as ramp metering, signal coordination, incident management, etc.
  - Capability of estimating traveler responses to traffic management strategies, including route diversion, departure time choice, mode shift, destination choice, and induced/foregone demand.
- Output performance
  - Ability to directly produce and output performance measures, such as safety measures (crashes, fatalities), efficiency (throughput, volumes, vehicle-miles of travel (VMT)), mobility (travel time, speed, vehicle-hours of travel (VHT)), productivity (cost savings), and environmental measures (emissions, fuel consumption, noise).
- Cost
  - Tool/Cost-Effectiveness for the task, mainly from a management or operational perspective.
- Experiences
  - The tool being used in your company (field) is often required



Combination of methods is also an option!

Děkuji Vám za pozornost

Demonstration of transportation planning - Case study

source: https://www.et.byu.edu

Transportation Planning Process

Objectives

- to assist governments in providing an adequate transportation system at an acceptable cost.

This involves

- modeling the behavior of the present system
- estimating future travel demand, and
- estimating how changes in the system will affect travel behavior and operation of the transportation system in the future

Basic elements of transportation planning

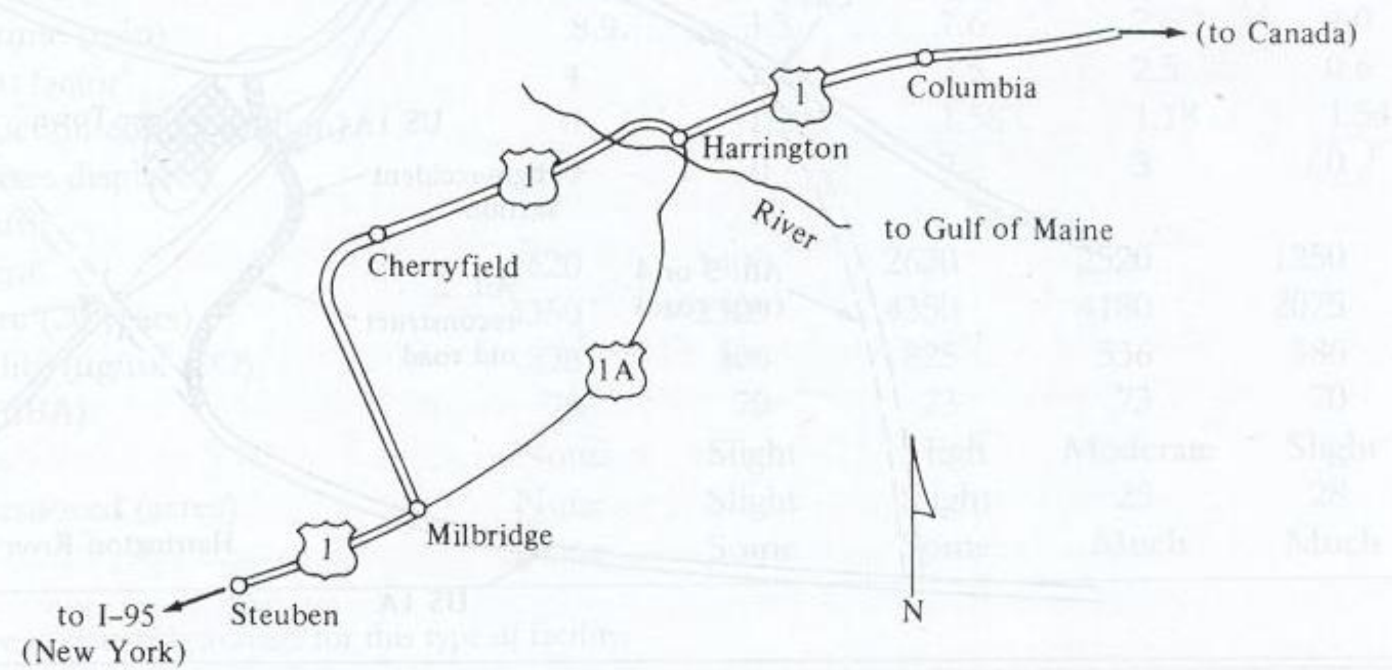
Situation definition	Inventory transportation facilities, Measure travel patterns, Review prior studies
Problem definition	Define objectives (e.g., Reduce travel time), Establish criteria (e.g., Average delay time), Define constraints, Establish design standards
Search for solutions	Consider options (e.g., locations and types, structure needs, environmental considerations)
Analysis of performance	For each option, determine cost, traffic flow, impacts
Evaluation of alternatives	Determine values for the criteria set for evaluation (e.g., benefits vs. cost, cost-effectiveness, etc)
Choice of project	Consider factors involved (e.g., goal attainability, political judgment, environmental impact, etc.)
Specification and construction	Once an alternative is chosen, design necessary elements of the facility and create construction plans

Example 11-1: Planning the relocation of a rural road (simple, yet good enough to explain the steps…)

Step 1: Situation definition:

➢ to understand the situation that gave rise to the perceived need for a transportation improvement

Figure 11.2 ■ Location Map for Highways U.S. 1 and U.S. 1A

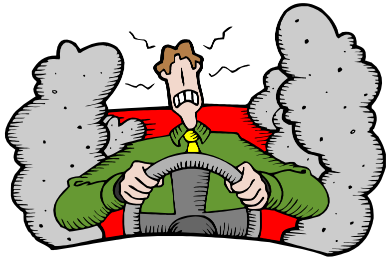


Step 2: Problem definition

Purpose of the step: Describe the problem in terms of the objectives to be accomplished and translate those objectives into criteria.

Example:

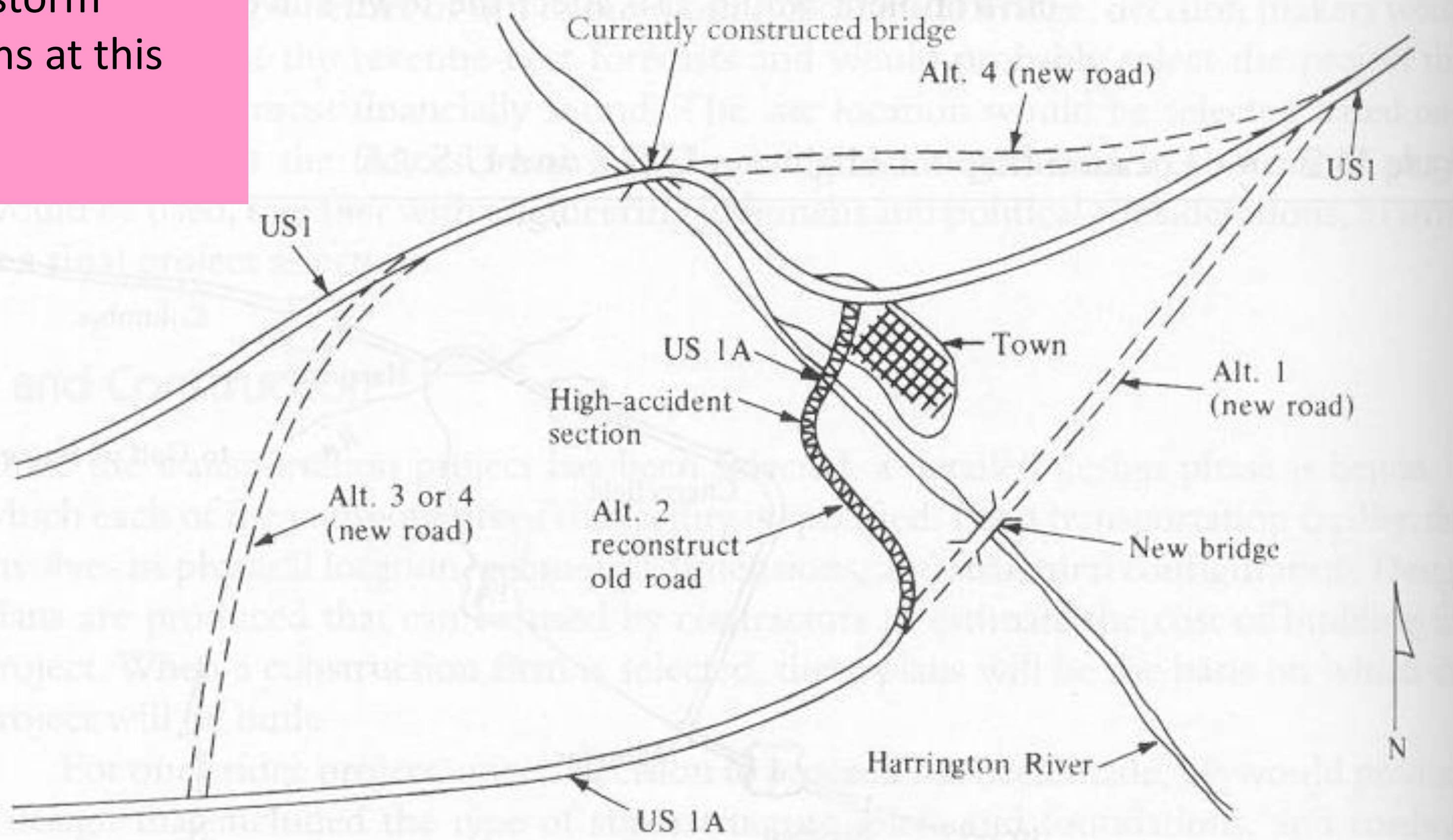
- Objective = Statements of purpose: Reduce traffic congestion, Improve safety, Maximize net highway-user benefits, etc.
- Criteria = Measures of effectiveness: Travel time, accident rate, delays (interested in reductions in these MOEs)



Step 3: Search for solutions

Brainstorm options at this stage.

■ Alternative Routes for Highway Relocation



Step 4: Analysis of performance

- Estimate how each of the proposed alternatives would perform under present and future conditions.

Table 11.1
Measures of Effectiveness for Rural Road Alternatives

	Alternatives				
Criteria	0	1	2	3	4
Speed (mph)	25	55	30	30	55
Distance (mi)	3.7	3.2	3.8	3.8	3.7
Travel time (min)	8.9	3.5	7.6	7.6	4.0
Accident factor[a]	4	1.2	3.5	2.5	0.6
Construction cost ($ million)	0	1.50	1.58	1.18	1.54
Residences displaced	0	0	7	3	0
City traffic					
Present	2620	1400	2620	2520	1250
Future (20 years)	4350	2325	4350	4180	2075
Air quality ($\mu g/m^3$ CO)	825	306	825	536	386
Noise (dBA)	73	70	73	73	70
Tax loss	None	Slight	High	Moderate	Slight
Trees removed (acres)	None	Slight	Slight	25	28
Runoff	None	Some	Some	Much	Much

[a] Relative to statewide average for this type of facility.

Step 4: (cont) Ranking of alternatives (in terms of MOE)

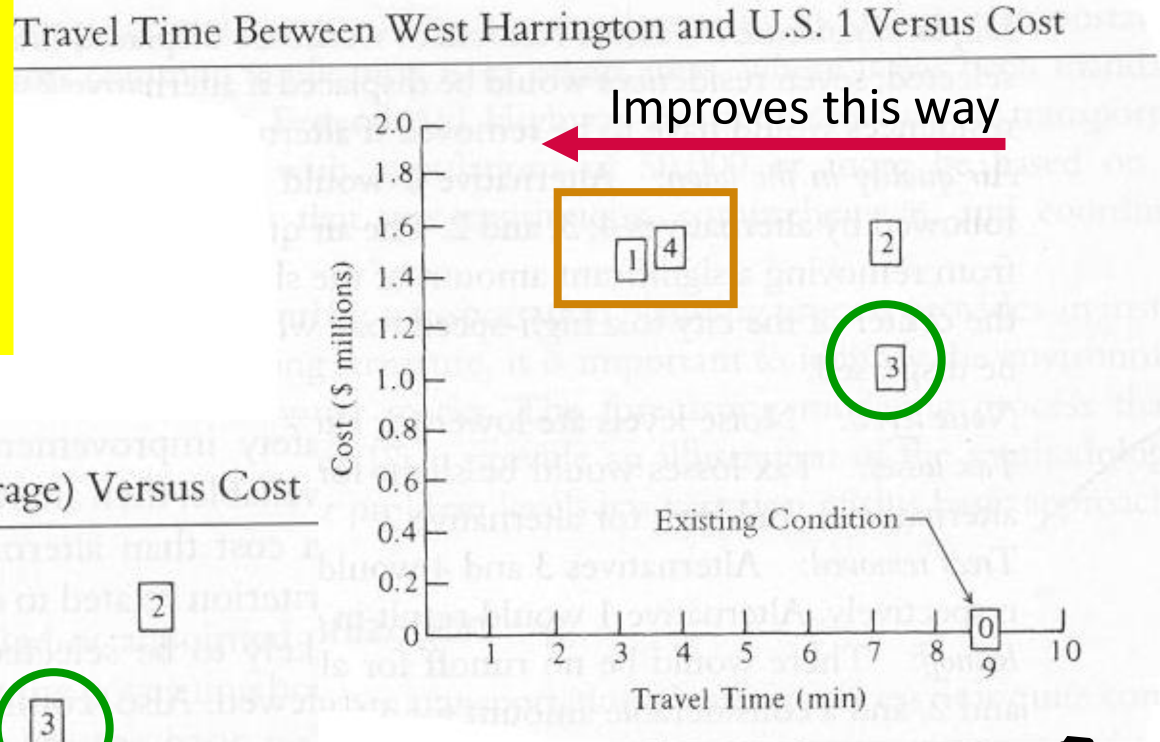
Table 11.2
Ranking of Alternatives

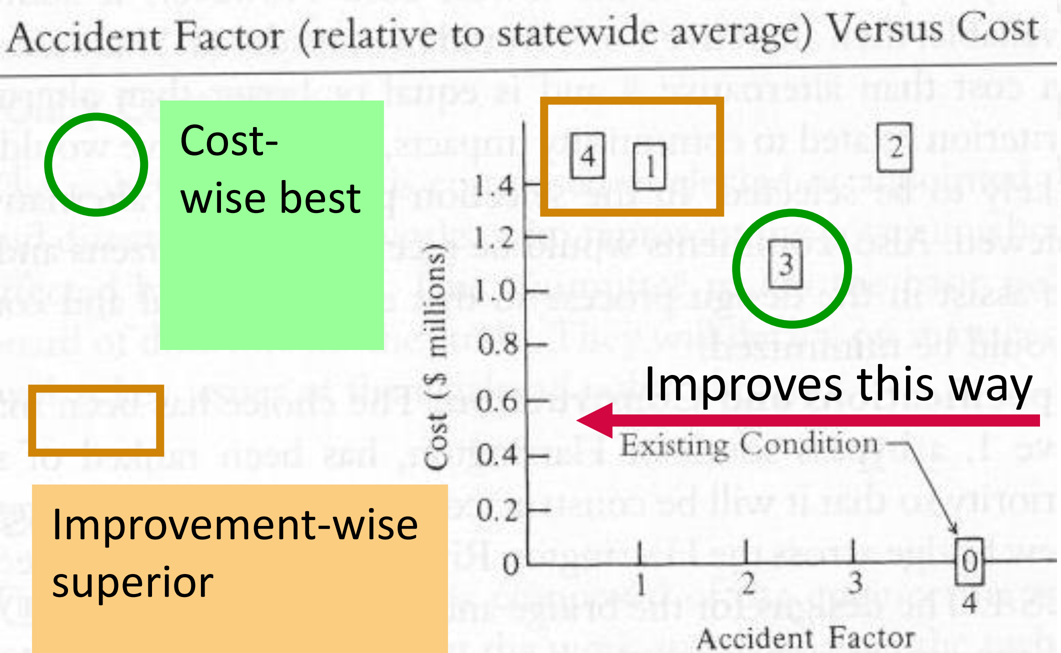
Criterion/Alternative	Alternatives 0	1	2	3	4
Travel time	4	1	3	3	2
Accident factor[a]	5	2	4	3	1
Cost ($ millions)	1	3	5	2	4
Residences displaced	1	1	3	2	1
Air quality	4	1	4	3	2
Noise	2	1	2	2	1
Tax loss	1	2	4	3	2
Trees removed (acres)	1	2	2	3	4
Increased runoff	1	2	2	3	3

Note: 1 = highest; 5 = lowest.
[a] Relative to statewide average for this type of facility.

Step 5: Evaluation of alternatives

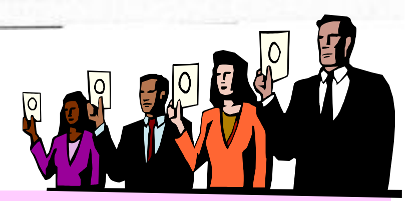
- ❑ Determine how well each alternative will achieve the objectives of the project as defined by the criteria.





Cost-wise best

Improvement-wise superior



This is a multi-objective evaluation problem.

Step 6: Choice of project

❖ Based on the alternative evaluation in Step 5, we will choose the best alternative for design and eventual construction. The best choice may not be built because of opposition by the people of the community that is affected.

Step 7: Specification and construction

❖ Once the project has been chosen, a detailed design phase is begun, in which each of the components of the facility is specified.

Urban transportation (demand) forecasting process

◈ This task is a technical effort to analyze the performance of various alternatives. We must define the study area first. Then further subdivide the area into traffic (analysis) zone, TAZ, for data tabulation and analysis.

- Homogeneous socioeconomic characteristics: e.g., high-income residential
- Minimum intra-zonal trips
- Use of physical, political, and historical boundaries, where possible
- Zones, once created, should not be subdivided into smaller zones during analysis
- Zones generating and attracting approximately equal trips, households, population, or area
- Use of census tract boundaries, where possible (easier to collect data from the Census Bureau's publications)